

Clinical Study

Enlarged laminectomy and lateral mass screw fixation for multilevel cervical degenerative myelopathy associated with kyphosis

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Abstract

BACKGROUND CONTEXT: Either an anterior approach or a posterior approach, which aims to decompress the spinal cord and restore the sagittal alignment, has been adopted to treat multilevel cervical degenerative myelopathy (CDM) associated with kyphosis. However, there is controversy on the optimal surgical strategy for the treatment of multilevel CDM with kyphotic deformity because of the complications of each surgical approach.

PURPOSE: The purpose of this study was to investigate the surgical efficacy of enlarged laminectomy (removing the inside edge of facet joints and decompressing the nerve foramina) and lateral mass screw fixation for the treatment of multilevel CDM associated with kyphosis.

STUDY DESIGN: A retrospective radiographic and clinical study to access the efficacy of enlarged laminectomy with lateral mass screw fixation in the treatment of multilevel CDM related to kyphosis.


PATIENT SAMPLE: A total of 43 patients (28 men and 15 women; average age, 59.6 years) with multilevel CDM correlated to kyphosis were obtained in the study.

OUTCOME MEASURES: All radiological data were recorded on computer-based measurement from preoperative or postoperative X-ray, magnetic resonance imaging (MRI), and computed tomography. All neurological parameters were accessed in each patient.

METHODS: Analysis consisted of: Japanese Orthopedic Association (JOA) score, recovery rate, curvature index (CI), the expansion degree and drift-back distance of the spinal cord, axial symptom severity, and C5 root palsy. The recovery rate based on the JOA score was calculated for each patient. Cervical CI as well as the expansion degree and drift-back distance of the spinal cord was measured using MRI. Axial symptom severity was quantified by a visual analog scale (VAS). Statistical analysis was performed using paired *t* test with significance set at $p < .05$.

RESULTS: Enlarged laminectomy was performed over a mean of 3.97 levels (range, 3–5 levels). Follow-up information was obtained at a mean of 2.8 years (range, 1.5–5 years) after surgery. Anal-

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level of maximum compression of the spinal cord ($t = 2.54$, $p < .001$), and VAS score ($t = 15.56$, $p < .001$). The mean spinal cord posterior shift was 4.72 ± 1.10 mm (range, 0–6.71 mm). X-rays confirmed that bone grafts were completely fused at a mean of 3 months after surgery. During the follow-up period, only two patients (4.7%) did not obtain complete recovery, four patients

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(9.3%) experienced axial symptoms; there were no C5 root palsy and instrument failures noted in this series.

CONCLUSION: Enlarged laminectomy with fixation for the management of multilevel CDM is demonstrated to be an effective strategy for improving neurological function, restoring the normal cervical lordosis, and decreasing the incidence of axial symptoms and C5 root palsy, but there is a need for randomized controlled studies with long-term follow-up to confirm and clarify these results.

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Keywords:

Enlarged laminectomy; Lateral mass screw fixation; Cervical degenerative myelopathy; Kyphotic deformity

Introduction

Multilevel cervical degenerative myelopathy (CDM), which is characterized by multisegmental spinal cord compression because of cervical spondylotic myelopathy (CSM), ossification of the posterior longitudinal ligament (OPLL), and cervical stenotic myelopathy, is a common spinal disorder all over the world [1]. Cervical kyphosis, which often leads to the coexistence of OPLL with CSM and cervical stenotic myelopathy [2], is the result of progressive degeneration of the facet joints and discs.

Surgical management for patients with multilevel cervical myelopathy related to cervical kyphosis aims to decompress the spinal cord and restore the normal sagittal alignment using either an anterior approach or a posterior approach [3,4]. However, multilevel anterior approach decompression has been associated with a high incidence of cord injury, cerebrospinal fluid leakage, graft failure, and pseudarthrosis [4–6]; in addition, the remaining anterior compression after posterior approach might hinder neurological recovery if the segmental instability and kyphotic deformity were not corrected in the surgical management [7,8]. The optimal surgical strategy for the management of multilevel CDM with kyphotic deformity remains controversial because of the shortcomings of each surgical approach.

The purpose of this retrospective study was to investigate the surgical efficacy of enlarged laminectomy with lateral mass screw fixation for the treatment of multilevel CSM and OPLL associated with kyphotic deformity.

Methods

Patient population

Between June 2006 and June 2010, data on 43 patients who underwent enlarged laminectomy and lateral mass screw fixation at our medical center were reviewed retrospectively. There were 28 men and 15 women (mean age, 59.6; range, 42–74 years). Patient inclusion criteria were the presence of one of the following: multilevel CDM related to kyphotic deformity because of CSM, cervical canal stenosis, or OPLL. Exclusion criteria were radiculopathy, trauma, tumor, and rheumatoid arthritis. The

follow-up periods ranged from 1.5 to 5 years (average, 2.8 years). All data regarding types of diseases, age, gender, decompressed levels, preoperative symptoms, and follow-up period were reviewed and statistically analyzed in Table 1. This study was approved by the institutional review board, and informed consent was obtained from each patient.

Operative technique

After intubation, the patient was placed prone in the head holder. A posterior midline incision was made, and the paravertebral muscles were retracted laterally. When the compressed levels were identified based on the preoperative data, screws (Medtronic Sofamor Danek, Memphis, TN, USA) were placed bilaterally with the Magerl technique. [9], rods of appropriate size were selected and bent to match the contour of the lateral masses, and secured to the lateral masses by screws. Then, enlarged laminectomy (including the removal of the inside edges of facet joints and adequate decompression of neural foramina) was performed from pedicle to pedicle to ensure adequate decompression of the spinal cord (Fig. 1). Bone grafts from dissected spinous processes were placed laterally on both sides of facet joints. The patients were required to stay in bed for the first week after surgery, and thereafter walking was allowed with a cervical collar for 2 months.

Clinical assessment

The neurological status of each patient was evaluated before and after surgery according to the Japanese Orthopedic Association (JOA) disability scale. The neurological recovery rate was calculated using the Hirabayashi method [10]:

$$(\text{postoperative JOA score} - \text{preoperative score}) / (17 - \text{preoperative score}) \times 100\%$$
Recovery rates were graded as follows: 75% and greater, excellent; 50% to 74%, good; 25% to 49%, fair; and less than 25%, poor.

The incidence of preoperative and postoperative axial symptoms was investigated in each group: severity was quantified by a visual analog scale (0 mm=no pain and 100 mm=worst pain) at the latest follow-up.

Radiological assessments

All patients underwent high-resolution magnetic resonance imaging (MRI) using a 1.5-Tesla Siemens MAGNETOM Symphony imager (Siemens, Berlin, Germany) before and after surgery. Data measurements were performed three times with 200% magnification for accuracy by the first author, and the mean value was used for analysis. Using both T2-weighted sagittal and axial images, the parameters were measured as follows:

1. Preoperative and postoperative cervical alignments were measured from the profile of neutral plain radiographs by cervical curvature index as described by Ishihara [11] (Fig. 2). “a1” was defined as the distance from the posterior inferior edge of the C3 vertebral body to line “A” and “a2 (C4), a3 (C5), and a4 (C6)” using the same method. “A” was defined as the distance from the posterior inferior edge of the C2 vertebral body to that of the C7 vertebral body.
2. Postoperative spinal cord shift was measured from the posterior borderline of the vertebral body to the anterior edge of the spinal cord at each level in midsagittal or axial images of T2-weighted MRIs performed after surgery (Fig. 3). Finally, the calculated average value of anterior subarachnoid space from the upper part of C3 to the end part of C7 was obtained for a given patient.
3. The anterior-posterior diameters of spinal cord at the radiographically most compressed levels were measured between postoperative and preoperative spinal cord expansions on identical T2-weighted axial cuts (Fig. 3).

Statistical analysis

A paired *t* test was used to assess statistical significance of changes between postoperative and preoperative parameters in each group. All statistical analysis was performed using Statistical Analysis System software (version 9.13; SAS Institute, Inc., Cary, NC, USA). A *p* < .05 was considered to be statistically significant.

Results

Surgical results

Enlarged laminectomy was performed over a mean of 3.97 levels (range, 3–5 levels) (Fig. 4). The average blood loss of enlarged laminectomy with fixation was 650 mL (range, 400–1,200 mL), and the mean surgery time was 2.5 hours (range, 2–4 hours).

Neurological results

The JOA scores had significantly improved in 95.3% of patients from a mean of 6.2 ± 1.9 preoperatively to 14.9 ± 1.4 postoperatively ($t=24.17$, $p<.001$). For neurological recovery rate, the results were excellent in 37 (86.1%) patients, good in 4 (9.3%), fair in 1 (2.3%), and

EVIDENCE & METHODS

Context

The use of a posterior approach for cervical decompression in the presence of kyphosis is controversial. The authors report their experience.

Contribution

In this case series of 43 patients with myelopathy and kyphosis due to degenerative disease, they report favorable neurological, functional, and alignment outcomes using wide laminectomy and lateral mass plating.

Implications

The findings might serve as a nidus for higher quality cohort or randomized trials.

poor in 1 (2.3%). The average neurological recovery rate was 79.86% (Table 2).

The postoperative visual analog scale score was 10.6 ± 5.3 , compared with the preoperative score of 37.4 ± 12.1 . The axial pain severity in neck/shoulder was markedly alleviated ($t=13.30$, $p<.001$) (Table 2).

Radiological results

X-rays confirmed that grafted bone was completely fused at an average of 3 months after surgery. Curvature

Table 1
Patient characteristics

Characteristics	Value
Total (n)	43
CSM	21
OPLL	14
Cervical stenosis	8
Mean age (y)	59.6 (42–74)
Gender	
Male	28
Female	15
No. of laminectomized levels	3.97 (3–5)
C3	5
C4	9
C5	12
C6	11
C7	6
Presenting symptoms	
Weakness	
Upper extremity	31
Lower extremity	23
Extremity hypesthesia	29
Gait instability	24
Hyperreflexia	33
Hoffman sign	21
Babinski sign	13
Clonus	8
Follow-up time (y)	1.5–5 (2.8)

CSM, cervical spondylotic myelopathy; OPLL, ossification of the posterior longitudinal ligament.

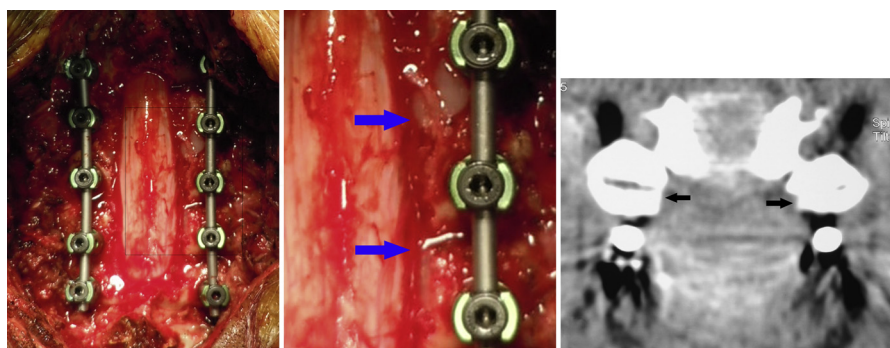


Fig. 1. (Left) Enlarged laminectomy and lateral mass screw fixation. (Middle) The arrows indicate the removal of the inside edge of facet joints and decompression of the nerve foramina in enlarged laminectomy. (Right) Postoperative cervical spine computed tomographic image.

index had significantly increased from $8.4\% \pm 2.5\%$ preoperatively to $19.3\% \pm 2.1\%$ postoperatively ($t=21.89$, $p<.001$). Cervical MRI in a neutral position indicated that the anteroposterior diameter at the level of maximum compression of the spinal cord significantly increased from 2.8 ± 1.3 mm preoperatively to 5.1 ± 0.9 mm postoperatively ($t=9.54$, $p<.001$), as well as increased in 98.43% of subjects postoperatively. The mean spinal cord posterior shift was 4.72 ± 1.10 mm (range, 0–6.71 mm) (Table 2).

Complications

Of a total of 43 patients, only two patients (4.7%) did not obtain complete recovery because of the severity of

symptoms before surgery, despite given a large dose of methylprednisolone, dehydrant, and neurotropic drugs. At the final follow-up, only four patients suffered axial symptoms, with an incidence of 9.3% (4 of 43). During the follow-up period, there were no C5 root palsy and instrument failure among patients.

Discussion

Multilevel CDM is a common disorder because of the multilevel spinal cord compression caused by CSM, OPLL, and cervical stenotic myelopathy [1]. Cervical kyphosis is the result of progressive subluxation of the apophyseal joints because of degenerative changes in the facet joints and discs. With the progression of kyphotic deformity caused by cervical degeneration, OPLL often coexists with CSM and cervical stenotic myelopathy [2].

Options of surgical strategy for multilevel CDM with kyphosis

Either an anterior approach or a posterior approach has been adopted by surgeons to treat cervical myelopathy secondary to multisegmental stenotic lesions such as continuous or mixed-type OPLL, multisegmental spondylosis, or developmental canal stenosis. We believe that there should be two aims in treating multilevel CDM with local kyphosis: one is to decompress the spinal cord and the other is to restore lordotic alignment. Multilevel anterior corpectomy seems to be a radical surgical option because of the high incidence of cord injury, cerebrospinal fluid leakage, implant complications, fusion failure, and grafted bone extrusion and subsidence, although it can correct in a limited way the local kyphosis [4–6]. Multisegmental posterior decompression might hinder neurological recovery because of the progression of kyphosis and segmental instability, as well as from complications such as axial symptoms and C5 root palsy [7,8]. Suda et al. [12] thought that local kyphosis exceeding 13° was a relative contraindication for posterior decompression and that then anterior decompression for correcting the kyphotic deformity should be recommended.

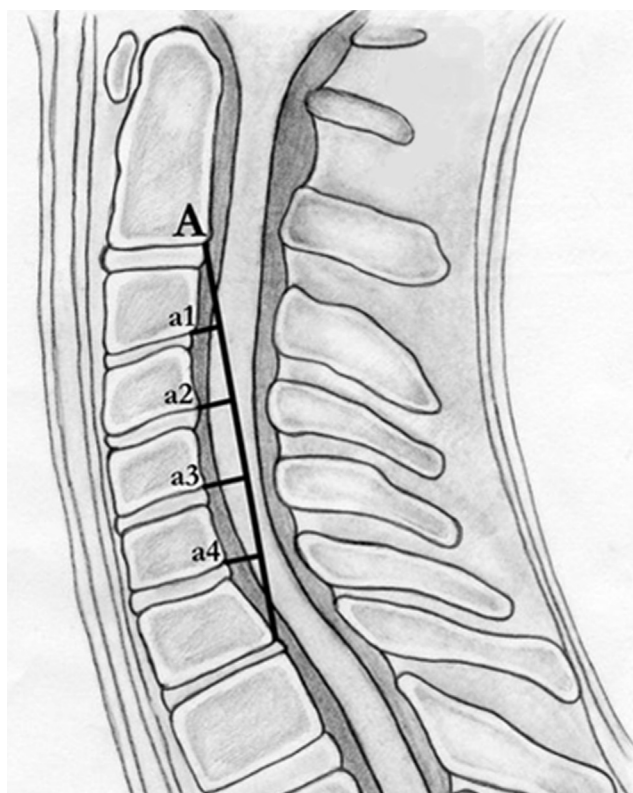


Fig. 2. Calculation of the cervical curvature index.

There have been significant debates about surgical strategy for multisegmental CDM with kyphotic deformity because of the deficits of each surgical approach.

In searching the world literature, we found that there were few reports on the efficacy of enlarged laminectomy (removing the inside edge of facet joints and decompressing the nerve foramina) with lateral mass screw fixation in the surgical management of multilevel CDM associated with kyphosis.

Intraoperative consideration of enlarged laminectomy and lateral mass screw fixation

Complications with enlarged laminectomy are relatively rare and mainly associated with compressive epidural hematoma or intraoperative neurological injury. To avoid large amounts of blood loss and postoperative epidural hematoma, careful attention must be paid to hemostasis when the surgeon removes the inside edge of the facet joints and decompresses the neural foramina. Bipolar electrocautery and absorbable gelatin sponge were used for hemostasis in the epidural space, and bone edges were waxed as necessary. In the present study, most of the neurological complications were related to ischemia-reperfusion injury of the spinal cord and nerve root crush injuries. In patients with severe spinal canal stenosis, the osteophytes and ossified ligaments of the neural foramina and inside edge of the lateral mass were removed by diamond drill until they were thin enough, and then they were cut with a 1- to 2-mm Kerrison rongeur and curettes. Additionally, intraoperative

neurophysiological monitoring was also an essential method to prevent iatrogenic neural injury [13]. Early detection afforded the surgical team an opportunity to perform rapid intervention and prevent injury progression or possibly to reverse impending neurological sequelae. Of 43 patients totally in this report, only two patients (4.7%) did not obtain satisfactory recovery despite of postoperative timely treatment for spinal cord. We presumed that the neurological deterioration may be associated with long-term severe compression before surgery and ischemia-reperfusion injury of the spinal cord.

Posterior cervical fixation with lateral mass screws is a popular and well-established technique used in the fusion and stabilization of the subaxial cervical spine. The accuracy of screw trajectory, screw length, technique of insertion, vertebral level, and size of the lateral mass have been reported to affect the relative safety of lateral mass screw placement [14]. The main complications of the Magerl technique were lateral mass fracture and instrumental failure resulting in breach of the screw into the soft tissues ventral to the lateral mass, which caused injury of vertebral artery, roots, and cervical sympathetic ganglion [15]. With the progression of posterior element degeneration, cervical lateral mass morphology may change. Therefore, using three-dimensional computed tomography, construction for postoperative patients with segmental kyphosis is very important. Successful lateral mass screw placement is highly dependent on surgeon experience. Moreover, grafted bone fusion plays a contributing role in preventing the screw/rod breakage or failure at the bone-metal interface with

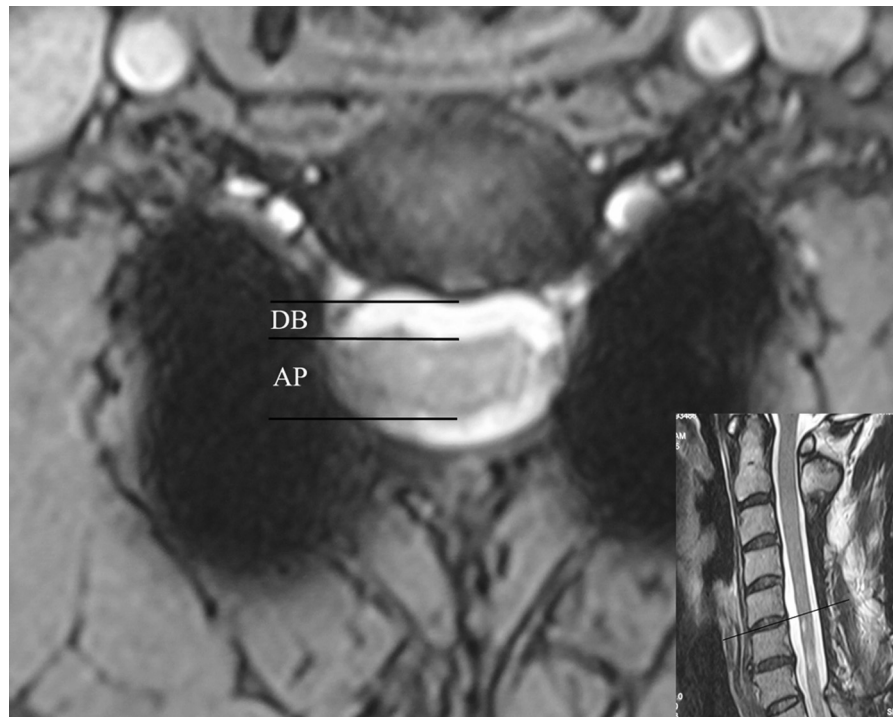


Fig. 3. Space available for the spinal cord. DB, drift-back distance; AP, the anterior-posterior diameter of the spinal cord at the radiographically most compressed level.



Fig. 4. A 55-year-old male patient underwent C3–C7 laminectomy with lateral mass screw fixation. (A–C) Preoperative X-rays show cervical kyphosis. (D) Preoperative midsagittal T2-weighted magnetic resonance imaging shows that cervical curvature index (CI) is 10.9%, and the anterior-posterior diameter of spinal cord at the radiographically most compressed level is 2.9 mm. (E–F) Postoperative computed tomography scans demonstrate full posterior enlarged decompression from C3 to C7 levels of the spinal cord. (G–H) Postoperative X-rays show that cervical curvature has been restored by lateral screw fixation, and the CI is 18.2%. (I) Postoperative X-ray shows that lateral screw fixation can maintain the cervical curvature.

loosening of the screws in bone. In our study, there were no patients who developed lateral mass fracture, screw/rod breakage or pullout, and pseudarthrosis.

Effect of enlarged laminectomy on neurological recovery

Enlarged laminectomy allowed adequate decompression of the spinal cord and nerve roots by removing spinous

processes, lamina, ligamentum flavum, and especially the inside edges of facet joints on each side. Excellent neurological recovery is associated with the extent of decompression and degree of the spinal cord shift [16]. Sodeyama et al. [17] demonstrated that posterior shift of the spinal cord of more than 3 mm led to a good clinical outcome. Their finding was supported by our current results of a mean spinal cord shift of 4.72 mm after enlarged laminectomy. In

Table 2
Comparison between preoperative and postoperative parameters

Parameters	Preoperation	Postoperation	t Value	p Value
JOA score	6.2±1.9	14.9±1.4	24.17	<.001
CI, %	8.4±2.5	19.3±2.1	21.89	<.001
AP diameters (mm)*	2.8±1.3	5.1±0.9	9.54	<.001
Drift-back distance (mm)	0	4.72±1.10	28.14	<.001
VAS score	37.4±12.1	10.6±5.3	13.30	<.001

JOA, Japanese Orthopedic Association; CI, curvature index; AP, anterior-posterior; VAS, visual analog scale.

* AP diameters: the AP diameters of the spinal cord at the radiographically most compressed level.

our institute, we have adopted enlarged laminectomy in patients with multilevel CDM related to kyphosis, which has obtained excellent neurological recovery.

However, enlarged decompression inevitably further increases cervical instability and degeneration [18]. Uchida et al. [19] confirmed that kyphotic deformity and mechanical stress in the cervical spine may play an important role in neurological dysfunction and that adequate correction of local sagittal alignment may help to maximize the chance of neurological improvement. Therefore, not only adequate enlarged decompression but also the reconstruction of cervical lordosis and stability should be taken into consideration in the surgical management of multilevel CDM with kyphosis.

Effect of lateral mass screw fixation on alignment restoration

Reconstruction of cervical stability is a key factor for successful treatment of patients with multilevel spinal cord compression lesions related to kyphotic deformity. Poor reconstruction is bound to offset the effects of decompression, whereas cervical stability can prevent further development of cervical instability and degeneration. Duan et al. [20] pointed out that posterior fixations could provide immediate stability to the cervical spine after laminectomy by reinforcing the posterior tension band, which attempted to prevent the loss of cervical lordosis and promote early neurological recovery. Paderer and Carbone [21] reported that the use of lateral mass screws for traumatic injuries of the cervical spine was associated with excellent maintenance of alignment and minimal complications. Aydogan et al. [22] demonstrated that lateral mass screws, which had been proved currently to be the most commonly performed posterior fixation method, could provide excellent three-dimensional fixations from C3 to C7. There were ample biomechanical experiments [23,24] suggesting that lateral mass screws could provide rigid fixation to the multiple cervical planes: flexion stability increased 92%, extension stability increased 60%, and rotation stability also improved greatly. In our study, plain radiographs had shown that posterior grafted bones had completely fused by 3 months postoperatively, and cervical curvature remained excellent without cervical curvature changes or instrument failures in the final follow-up. This further confirmed that

lateral mass screw fixation can effectively restore and maintain the normal cervical lordosis, providing a stable biomechanical environment for neurological recovery.

Effects of curvature restoration and spinal cord shift on complications

The incidence of axial symptoms can be as high as 30% to 80% [25], but the exact reason is unknown. Takeuchi et al. [26] suggested that axial symptoms were related to cervical kyphotic deformity. Otani et al. [27] thought that lateral retraction of paravertebral muscles attached on the cervical spine and removal of lamina and ligamentum flavum in laminectomy, especially the semispinalis attached on the C2 spinous process, increased the flexion mechanical stress, which may be a significant factor in the development of axial symptoms. Motosuneya et al. [28] reported that reconstruction of the posterior tension band for cervical stenotic myelopathy contributed to decreasing the incidence of axial pain. The present study showed that postoperative axial symptom severity was significantly lower than preoperative levels, with a lower incidence (9.3%) compared with previous research [25]. We speculate that lower axial symptom severity after surgery may correlate with reconstruction of the cervical posterior tension band and restoration of cervical curvature.

C5 palsy is a less severe but much more common and perplexing problem, with average incidence rates of 4.6% (range, 0–25%) in patients with CSM and 8.3% (range, 3.2–28.6%) in patients with OPLL [29]. To a large extent, spinal cord drift can be limited by several factors. Anatomically, the tethering effects on nerve roots will ultimately limit dorsal spinal cord shift [30]. The compressive elements such as soft tissues or osteophytes that impinge on the neural foramina, if not removed completely, may limit the mobility of the nerve roots and therefore impede postoperative cord shift [31]. Additionally, Chen et al. [30] suggested that C5 palsy may also be correlated with excessive cervical lordosis. The normal cervical spine has a 31° to 40° lordosis. Excessive reconstruction of cervical curvature may induce C5 palsy, whereas inadequate lordosis may not reduce ventral spinal cord compression from OPLL or herniated discs. Therefore, both reconstruction of the cervical lordosis and adequate posterior decompression (especially of the neural foramina) contribute to decrease the incidence of C5 root palsy. In the present study, there was no C5 palsy occurring in any patient because of the removal of the inside edge of facet joints, which provided enough space to drift back for the nerve roots. We believe that both appropriate curvature restoration and enough nerve foramina decompression may play an important role in reducing the occurrence of C5 palsy.

Conclusion

The present study showed that enlarged laminectomy with lateral mass screw fixation was an effective surgical

strategy in restoring normal cervical alignment, obtaining excellent neurological recovery by posterior shifting of the spinal cord, and decreasing the occurrence of complications such as axial symptoms and C5 root palsy by completely removing the soft tissues or osteophytes in the neural foramina. There remains a need for randomized controlled studies with long-term follow-up to clarify these results.

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